Coastal Mixing

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LONG-TERM GOALS

I seek to understand the mechanisms of turbulence and mixing in shallow water sufficiently well to be able to specify useful parameterizations for coastal circulation models. I seek to understand the links between mixing rates and the circulation and productivity of the coastal ocean.

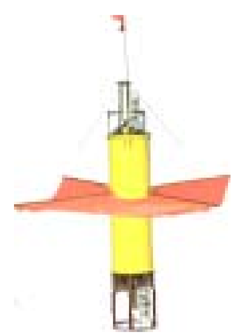
OBJECTIVES

The short-term objective (2000-2001) is to make mixing and circulation measurements in the Oregon upwelling system and test the theoretical turbulence parameterizations developed by D'Asaro and Lien (2000) using this data.

APPROACH

Neutrally buoyant Lagrangian floats were deployed on the Oregon Shelf during the summers of 2000 and 2001. The float motion measure water parcel trajectories. High frequency measurements along the float trajectories measure the mixing dynamics.

During the last decade, we have developed a new type of neutrally buoyant float (see picture[1]) designed to be used in energetic turbulent flows such as those found in the top and bottom boundary layers of the ocean. A combination of accurate ballasting, compressibility matched to that of seawater and high drag is used to make these floats follow the motion of water parcels accurately (D'Asaro et. al 1976). Water velocity is inferred from the motion of the floats; high frequency fluctuations in velocity can be used to infer mixing rates if the mixing is sufficiently energetic (Lien et. al 1998).



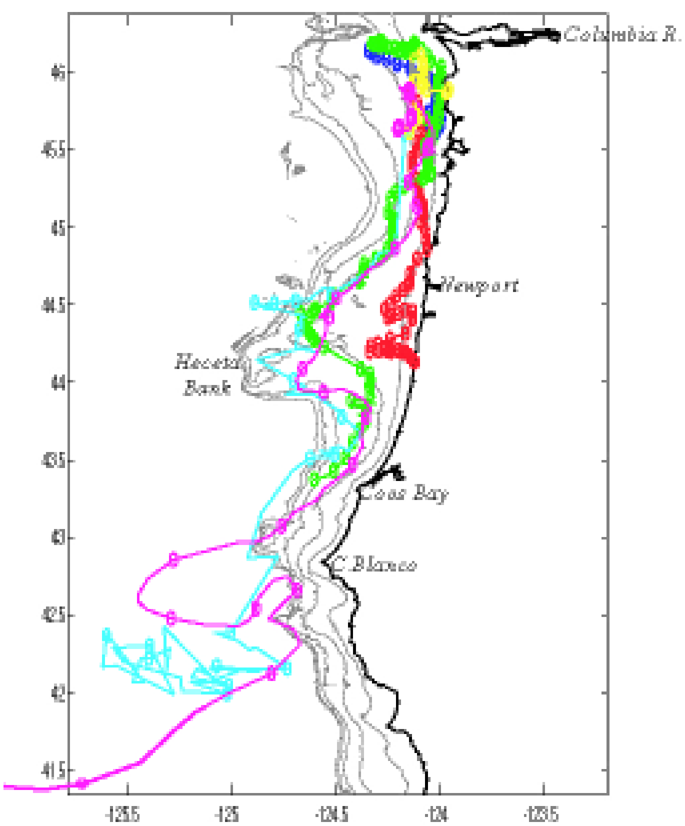
A new variety of these floats was used for the first time in the 2000 Oregon upwelling measurements. These can operate both as Lagrangian floats, by varying their buoyancy to become neutrally buoyant and opening their cloth drogue to create a large drag and as vertical profilers, by folding the drogue

[1] The float is a yellow cylinder, about 1 m long, with instruments on top and bottom and an orange cloth cylindrical drogue at the center.

and varying their buoyancy to profile up or down. They measure temperature and salinity of the water surrounding them (using a CTD) and the distance from the bottom (using an acoustic altimeter). The CTD is also used to control the float's buoyancy so that on average, it remains near a chosen isopycnal. At the top of each profile (twice a day) a GPS fix is obtained and and a subset of the data telemetered by the ORBCOMM satellite system. It is available for viewing and/or downloading on a web site. Most of the data is stored internally. The float behavior can be adjusted by sending commands to the float via satellite. The floats have a duration of months and can carry a variety of sensors.

WORK COMPLETED

In the summers 2000 and 2001, a total of 6 floats were deployed. The 2001 floats are still in the water and will be recovered in mid-October. Two of the 2001 floats were equipped with a Doppler sonar and two CTD's and could thus measure shear, strain and Richardson number. One 2001 float was equipped with a fluorometer and light sensor (funded internally by APL) and could thus measure the biological response to upwelling. These measurements were made within the context of extensive SeaSoar, moored, aircraft and radar measurements of the same region as part of the GLOBEC program.



The figure shows the float trajectories from the two years. Floats were deployed somewhat south of the Columbia River by fishing boats. They all travelled southward. Two grounded on beaches and were recovered. The others were recovered by ship.

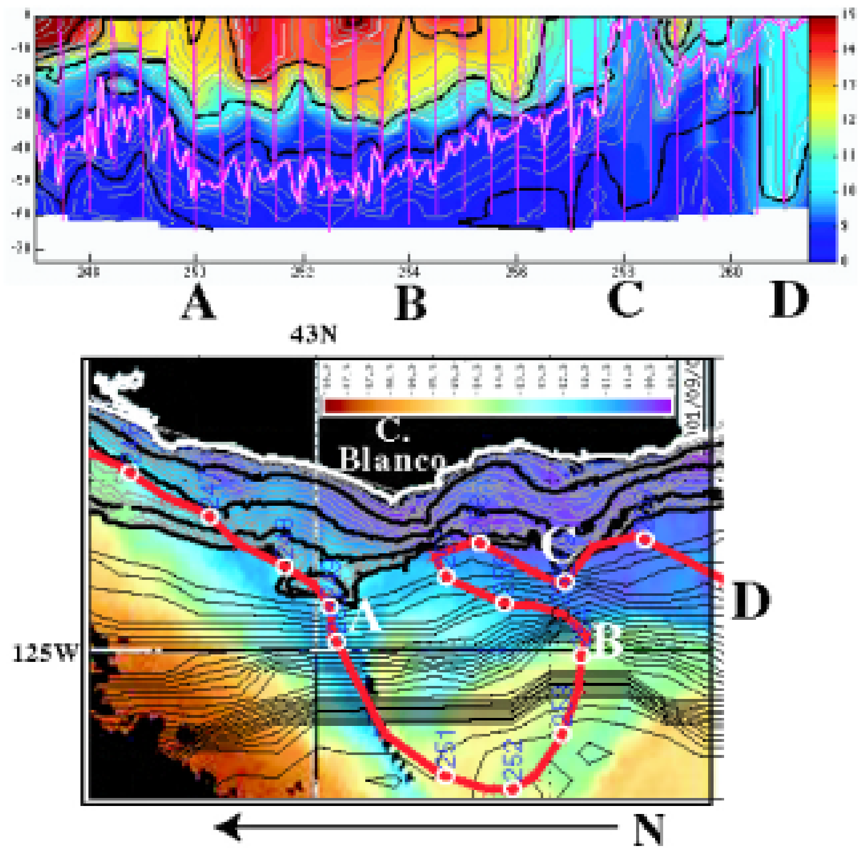
RESULTS

Circulation over Heceta Bank: The three floats that transit Heceta Bank show little evidence of trapping or eddy formation. This suggests a strong circulation on the outer part of the bank. However, one float on the inner bank moves much more slowly, suggesting a weak flow in this region.

Upwelling: These floats make accurate measurements of vertical velocity and thus can directly measure where upwelling occurs. The data shows both the traditional wind-forced upwelling, particularly on the nearly two-dimensional shelf between Heceta Bank and the Columbia River, and strong mesoscale-eddy driven upwelling. This seems to occur in conjunction with sharp cyclonic turns in the circulation.

The figure below shows the most dramatic of these eddy-induced upwellings. The top panel shows the depth-time trajectories of a float, superimposed on density contours (black) and temperature shading.

The float starts at depth of 40-50m, where it has resided since launch. From B to C, however, it upwells to the surface, briefly descending from C to D and then remaining on the surface for the next 5 days (not shown).



The trajectory of the float is shown in the bottom panel superimposed upon a colored satellite sea surface temperature image. White circles along the (red) float trajectory mark GMT midnight. The float travels along the shelf until it reaches the point of Cape Blanco (A) and circulates around a cyclonic eddy back to the shelf break (B). It then dramatically retroflects in strong anti-cyclonic motion corresponding to the time of upwelling (C). It then shoots SW, on the surface but off the figure, in the large pool of cold water south of Cape Blanco, eventually subducting on the far edge of the pool. All of this data was transmitted by satellite; when the float is recovered a more detailed view of the this event will be possible.

Vertical mixing: High frequency velocity fluctuations from the summer 2000 data do not show the smooth spectral forms anticipated by D'Asaro and Lien (2000). Instead, a large peak near the Nyquist frequency is found. This is at least partially due to energetic solitary waves which lead to large vertical excursions, but little mixing. Diffusivities along the float trajectories are well below 1 cm^2/s at all times.

Horizontal mixing: High frequency temperature and salinity fluctuations vary widely in amplitude and cannot be explained by vertical mixing alone. These appear to be the result of strong horizontal mixing. Rates cannot yet be determined.

Biological/Physical Interactions: The florometer equipped float traversed a strong chlorophyll maximum on the south flank of Heceta Bank. In the moving coordinate system of the float, the maximum had the characteristic signatures of a temporal bloom: strong growth in the mixed layer, followed by decay and a secondary growth and decay below the mixed layer. This suggests that the high productivity of Heceta Bank is not due to local upwelling of nutrients, but to the Bank being downstream of the upwelling on the Northern Oregon shelf.

IMPACT/APPLICATIONS

The floats have proven to be robust and useful platforms for measuring various aspects of the coastal ocean over periods of many months. The satellite telemetry allows real-time access to their data and the flexible design should allow a variety of sensors to be installed.

TRANSITIONS

None

RELATED PROJECTS

These floats are nearly identical to those that will be used in the upcoming CBLAST study of air-sea interaction in hurricanes.

REFERENCES

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